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INVESTIGATION AND OPTIMIZING OF AIR SEEDER PERFORMANCE IN SEEDING CHICKPEAS

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Final Report

Investigation and Optimization of Air-Seeder Performance in Seeding Chickpea

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1. Abstract

Tests were conducted using air cart/air distribution systems from Bourgault, Flexi-Coil, and Morris to quantify effects on chickpea damage (cracking and germination). Initial impact testing was done to determine the effect of chickpea type and variety on seed damage. Impact testing revealed that desi chickpea were most susceptible to damage compared to kabuli, with a range in damage from 6.9% in B-90 to 29% in Anna and Desiray. Kabuli chickpea were less damaged by impact with less than 5% damage for CDC Xena, CDC Diva, and Sanford to a maximum of 10.4% for CDC Yuma.

The main variety selected for testing with the air cart/air distribution system testing was CDC Yuma due to the varieties susceptibility to damage, market value, and seed cost per acre. Metering systems had a very small effect on damage with a maximum of 0.8% of total damage. Changes in seed damage, due to ground speed were very small. Overall seed damage through the air cart/air distribution systems was higher, as fan speed increased. However, all three manufacturers' systems resulted in overall seed damage of less than 3% at fan speeds up to baseline +25%.

Coefficient of variation for seed distribution was within PAMI standards at all tested fan speeds.

2. Introduction

Chickpea acreage across the prairies has increased dramatically over the last number of years. The seed costs involved in growing the crop are substantial compared to other crops grown due to the high seeding rates required. The seed itself is also very susceptible to damage, and therefore, needs to be handled with care. Many farmers seed, or are thinking about seeding, with air seeders and question whether or not this method of seeding is appropriate for chickpea due to their fragile nature. This report will quantify the damage caused to chickpea by three different types of air seeders run at different ground and fan speeds to determine operating parameters that will minimize seed damage for each system.

3. Scope of Test

3.1 Preliminary Impact Test

The objective of the preliminary work was to test various varieties of desi and kabuli chickpea for mechanical damage due to impact. The tests were not designed to duplicate air seeder performance, but to provide sufficient impact to compare the relative susceptibility to damage among the chickpea varieties. The varieties selected for air cart/air distribution testing were based on a combination of factors, including impact damage, market value of the variety, and seed cost per acre.

3.2 Impact Test Methodology

Four varieties of large kabuli (CDC Yuma, CDC Xena, CDC Diva, Sanford), three varieties of small kabuli (Verano, CDC Chico, B-90), and three varieties of desi (Anna, Desirary, Myles) chickpea were obtained for the tests. The chickpea were placed in a humid environment for one week to standardize moisture content. A Labtronics 919 moisture meter was used to determine moisture content of each chickpea variety. Approximately 4.4 lb (2,000 g) of each variety were hand screened and hand cleaned to remove all cracked, chipped, or damaged seeds. This resulted in one, 1.1 lb (500 g) check sample for germination and three, 1.1 lb (500 g) test samples for the impact tests.

A number of impact protocols were developed to differentiate impact damage among chickpea varieties. Gravity impact, using gravity to accelerate seeds at heights as high as 20 ft (6 m), were not successful in providing enough impact velocity to generate physical damage differences among the varieties. As a result, impact velocity was increased using compressed air to increase impact damage. The test set-up successfully used for the experiment consisted of a vertical 8 ft (2.4 m), 2 in (51 mm) inside diameter PVC pipe (**Figures 1** and **2**). At the top of the pipe a Y was installed with an 18 in (45 cm) PVC pipe angled at 45 ° to the vertical. A funnel was attached to the top of the pipe to direct seeds into the system. A compressed air discharge nozzle was attached to the top of the vertical pipe to provide a high velocity air stream within the pipe. Air velocity at the discharge end of the vertical pipe was measured at 95 ft/sec (29 m/sec). Just below the bottom (discharge end) of the pipe, a steel impact plate was mounted at 50° from horizontal. The steel plate was mounted inside a plastic rectangular tub with most of the surface covered to prevent escape of the impacted seed. Seeds were poured into the funnel, and flowed into the vertical pipe, where they were accelerated with the compressed air blast until they impacted the steel plate. The

1.1 lb (500 g) test samples were evenly poured into the funnel over a 20 to 25 second interval. To increase the damage, each sample was run through the test twice. Following the second impact run, seeds were collected from the plastic tub for cracking and germination analysis. Cracks were removed by hand screens and then hand cleaned to remove all cracked or broken seeds. The remaining clean sample was sent to Discovery Seed Labs for germination tests. Seed samples were weighed for the impact and air cart/air distribution test using a Shimadzu BW 3200 electronic scale. Air speed was measured using an Omega model HHF710 anemometer. Time measurements were conducted with a Micronta stopwatch.

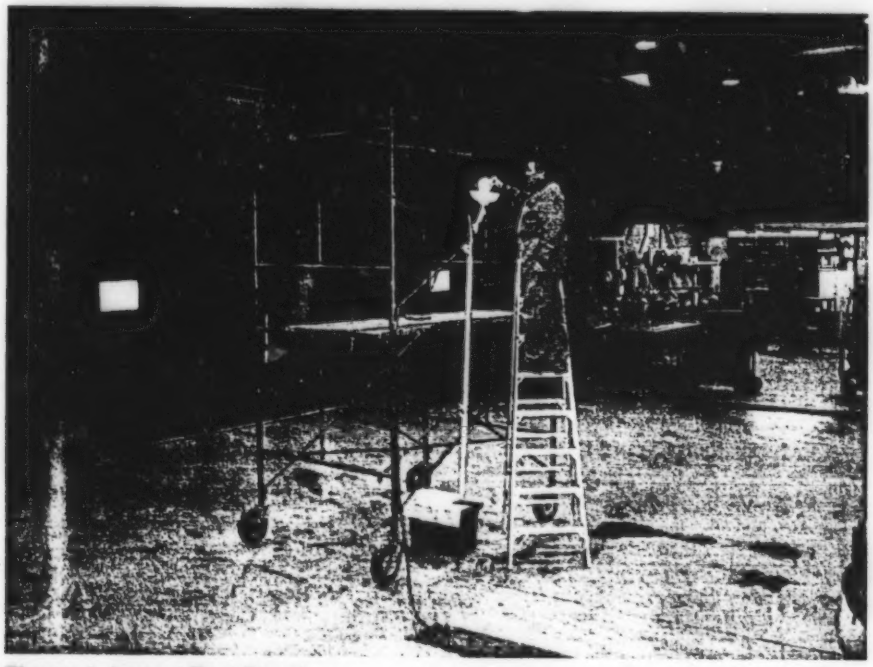


Figure 1. Impact Test Stand.

Figure 2. Impact Test Stand.

3.3 Seed Damage Assessment

Chickpea damage was evaluated using two different methods. The first method was by visual inspection of physical seed damage including splits, cracks, or any seed coat penetration. Physical seed damage was quantified by removing damaged seeds from the sample and expressing this weight as a percent of the original sample weight. The second assessment method was to quantify hidden damage to the seed. Hidden damage was determined by sending the good, undamaged seeds to Discovery Seed Labs for germination tests. Total damage was calculated as the sum of percent physical damage plus the percent reduction in germination. Net damage due to seed metering and distribution was calculated by comparing the difference between the physical and germination damage of the treated samples with check samples.

3.4 Impact Test Results and Conclusions

Impact results confirmed observations that desi chickpea are more susceptible to damage then kabuli chickpea (**Table 1**).

Table 1. Effect of Impact on Chickpea Damage.

Type	Variety	Moisture Content (%)	Check Germination (%)	Germination Loss (%)	Physical Cracks (%)	Total Damage (%)
Large kabuli	CDC Yuma	12.2	95	1.3	9.1	10.4
	CDC Xena	12.4	92	1.3	3.3	4.6
	CDC Diva	12.4	98	2.0	2.7	4.7
	Sanford	12.3	99	2.3	2.0	4.3
Small kabuli	Verano	12.4	72	4.7	14.4	19.1
	CDC Chico	12.6	96	3.7	4.9	8.6
	B-90	11.9	96	3.7	3.2	6.9
desi	Anna	12.1	88	5.7	23.7	29.4
	Desiray	12.0	65	0.0	29.8	29.8
	Myles	11.9	92	0.3	13.8	14.1

Desi varieties, Anna and Desiray, had the highest level of damage at approximately 29.5%, while Myles was much lower at 14.1% damage. The small kabuli variety, Verano, had 19.1% damage, while the other small kabuli varieties, CDC Chico and B-90, were 8.6 and 6.9% respectively. All of the large kabuli varieties, except CDC Yuma, averaged less than 5% impact damage. CDC Yuma had 10.4% damage, which was more than double the damage level of the other large kabulis.

The levels of damage were much higher in the impact test compared to the actual air tank/air distribution tests. The impact test was deliberately set up to produce high damage levels in order to show differentiation among varieties. As a result, the high levels of damage in some of the impact tests should not be interpreted as a problem when using air tanks/air distribution systems in the field.

CDC Yuma was chosen as the main variety for the air tank/air delivery tests due to a combination of relatively high impact damage, potential market value of the variety, and high seed costs. Sanford and Desiray varieties were also used in one sequence of air tank/air delivery tests at one set of conditions due to their relatively large seeded acres in Saskatchewan.

4. Project Methodology for Air Tank/Air Delivery Tests

4.1 Air Tank/Air Delivery Systems

Bourgault, Flexi-Coil, and Morris provided air tank/air delivery systems for the project. Equipment provided by each manufactures was in production or near production. Details of each manufactures systems are described in **Sections 4.4.1**.

4.2 Seed Preparation and Maintenance

Certified CDC Yuma, CDC Xena, and Desiray were obtained for the air tank/air delivery tests, the certified seed was re-cleaned by screens to minimize initial cracked or broken seeds.

The CDC Yuma was obtained at approximately 13.5% moisture. It was then placed in mini bulk bags and stored in a humidified environmental chamber to maintain the moisture content. The CDC Xena and Desiray were obtained at 10-11% moisture. The seed was spread out and water added to raise the seed moisture level to approximately 13% moisture. The moistened CDC Xena and Desiray were also stored in mini bulk bags in the environmental chamber.

4.3 Seed Sampling Methodology

All check samples were collected as the seed was transferred prior to entering the air cart. Metering system samples were collected using the standard calibration method from each manufacturer at a simulated groundspeed of 4 mph (6.4 km/h). Air tank/air distribution system samples were collected in plastic tubs at the end of each air distribution hose. Samples from each delivery hose were combined (following weighing) and divided into 5 to10 lb (2.3 to 4.5 kg) samples using a Seedburo seed divider. This sample was subdivided into four equal samples with the seed divider. Each of the four samples were then separately assessed for damage. A separate test was conducted with the seed divider to confirm that no seed damage was caused by the divider.

4.4 Test Methodology Common to all Manufacturers

4.4.1 Air Cart/Air Delivery Systems

Each machine was set up for static testing on a flat floor in PAMI's Crops Processing Centre. All machines were configured to factory specifications with representatives from each company present during final set-up and initial testing. Manufacturer's seed boots were replaced with a "standard" boot to ensure machine performance was not affected

by boot design. The standard boot consisted of 12 in (30 cm) x 1.25 in (3.1 cm) ID round steel tube with a 30° bend in the middle (**Figure 3**). The discharge end of each air system delivery hose was taped to the top of the steel tube and a rubber hose was attached to the lower end of the tube to direct the chickpea into the plastic catch tubs.

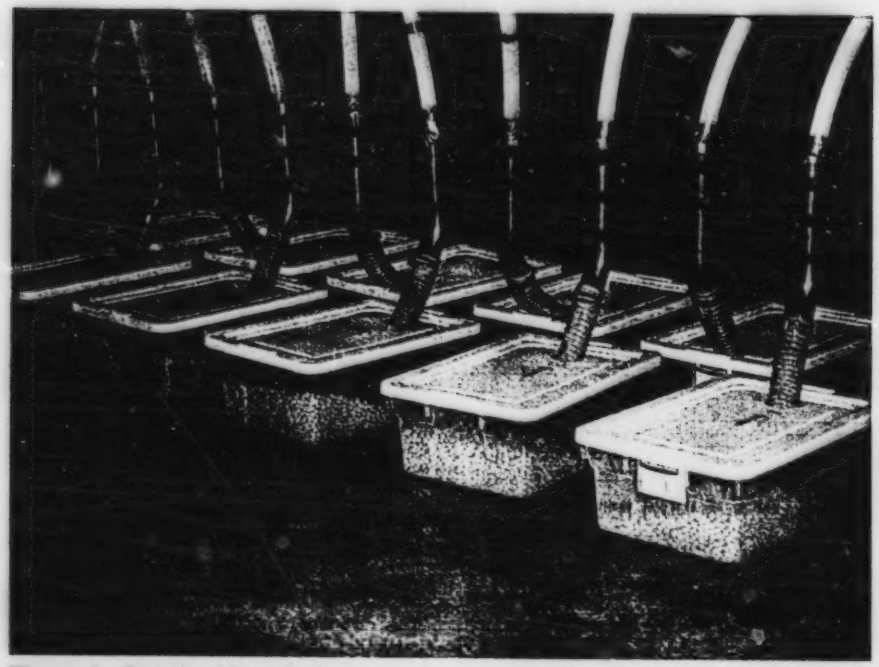


Figure 3. Standard Boot Setup.

Each air tank was loaded with chickpea using a mini-bulk bag with an extended discharge sock. During filling, the bag was suspended above the tank and the sock extended to the bottom of the tank, as shown in (**Figure 4**).

Figure 4. Filling Air Tank with Mini Bulk Bags and Extended Sock.

The extended sock was used to minimize handling damage during tank loading. A sample of the seed was collected prior to loading the tank. This sample was the check sample and was used to provide baseline information on physical seed damage and germination percentages. Each time a new batch of seed was loaded into the tank a new check sample was taken for comparison with the sample runs through the air tank/air delivery system.

All air tank/air delivery systems were calibrated using CDC Yuma at a seed rate of 160 lb/ac (179 kg/ha), using the manufacturers instructions, at a simulated ground speed of 4 mph (6.4 km/h). The systems were not recalibrated for seed rate at 5 or 6 mph (8 or 9.6 km/h). All product was weighed using a Shimadzu BW3200 electronic scale.

Metering system damage was measured separately from overall system damage to identify the source of the damage. Metering damage tests were conducted at a simulated ground speed of 4 mph (6.4 km/h). Each machine was set up to catch metered samples using the factory methodology and the metering system was engaged at 4 mph (6.4 km/h). The metering system was run for approximately 30 seconds to achieve steady state, which was followed by a timed collection of metered seed. This sample was analysed for physical and germination damage as

outlined in **Section 3.3**. The check damage was subtracted from the metered sample and used to determine any net metering damage.

Minimum fan speeds were determined for each system at 4, 5, and 6 mph (6.4, 8, and 9.6 km/h) simulated ground speed. All fan speeds were set using a photo tachometer under no load conditions (no seed metered or in air delivery system). Fan speeds were also measured and recorded under load (**Tables 2, 3** and **4**). Thirty-second trial runs were completed at the target seeding rate and ground speed and fan speed was decreased until unacceptable seed flow (pulsed distribution) or line plugging occurred. The fan speed prior to the plugging was determined to be the minimum or base fan speed for a given machine configuration, ground speed, and seed rate.

To determine the effect of fan speed and ground speed on CDC Yuma chickpea damage and distribution accuracy (CV), 12 tests were run with each machine. Simulated ground speed of 4, 5, and 6 mph (6.4, 8, and 9.6 km/h) were run at fan speeds of baseline, baseline plus 15%, baseline plus 25%, and maximum manufacturers recommended fan speed. The individual runs were not replicated, as originally planned, due to the length of time the system had to run to achieve stable conditions.

All manifolds on the machine were colour coded and each manifold (delivery hose) was numbered. Colour coded and numbered tubs were placed under each run for collection purposes. Product was then metered through the system (at a set fan and ground speed) into the tubs. Test runs were 2 minutes at 6 mph (9.6 km/h), 2.5 minutes at 5 mph (8 km/h), and 3 minutes at 4 mph (6.4 km/h). The length of run was adjusted for ground speed to keep the catch weights of the tub samples constant. Seed weight in each tub was recorded to determine coefficients of variation of seed distribution for each manifold and the overall machine. Coefficients of variation were calculated only to ensure that the air seeder was functioning within normal operating parameters.

Representative samples were taken from each of the 12 test runs by dividing the combined seed down to an acceptable size using a Seedburo seed divider. The samples were analyzed for physical cracks and germination. Total damage from the air tank/air distribution system at a particular fan speed and ground speed was determined by subtracting check damage from the treatment damage. Similarly, the damage from the air distribution system was determined by taking the total damage from the air tank/air distribution system subtracted by the metering system damage. The data reported is the average of 4 sub-samples taken from each run.

One standard protocol air tank/air distribution damage run was conducted using the Desiray chickpea (smaller seed). The test was done at 5 mph (8 km/h) at base plus 25% fan speed at a seeding rate of 80 lb/ac (90 kg/ha). Total damage for the system was determined as previously described.

Another single standard protocol air tank/air distribution damage run was conducted using CDC Xena chickpea (larger seed). The test was done at 5 mph (8 km/h) at maximum fan speed at a seeding rate of 180 lb/ac (202 kg/ha). Total damage for the system was determined as previously described.

Bourgault: The Bourgault system included a Bourgault 3225 air cart with an air kit mounted on test stands. The air kit was designed for a 40.8 ft (12.4 m) air drill with 9.8 in (25 cm) row spacing. Seed was metered from the air cart equipped with the Positive Displacement Metering System (**Figure 5**) into one primary 4.83 in (12.3 cm) ID distribution hose. This hose ran past the rear of the air tank where it entered the bottom of the primary manifold with five 2.5 in (6.35 cm) ID outlets. Each of these hoses ran to a secondary manifold. Each secondary manifold had 10 delivery hoses of 7/8 in (2.2 cm) ID hose. The 7/8 in (2.2 cm) delivery hoses were inserted into the standard seed boot/collection tub apparatus. The Bourgault was equipped with the optional Quick Inspection manifold with poly caps (**Figure 6**).

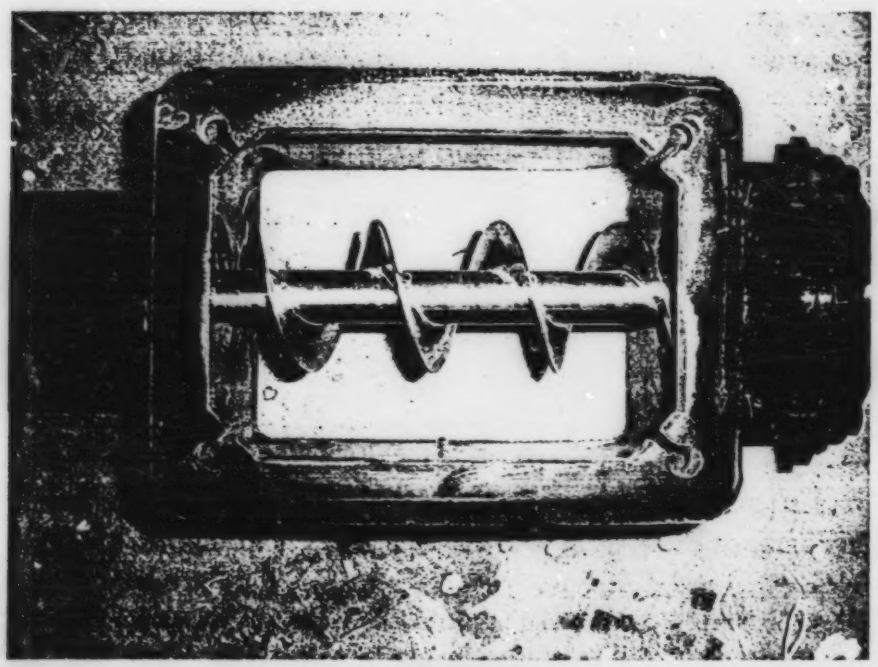


Figure 5. Positive Displacement Metering System.

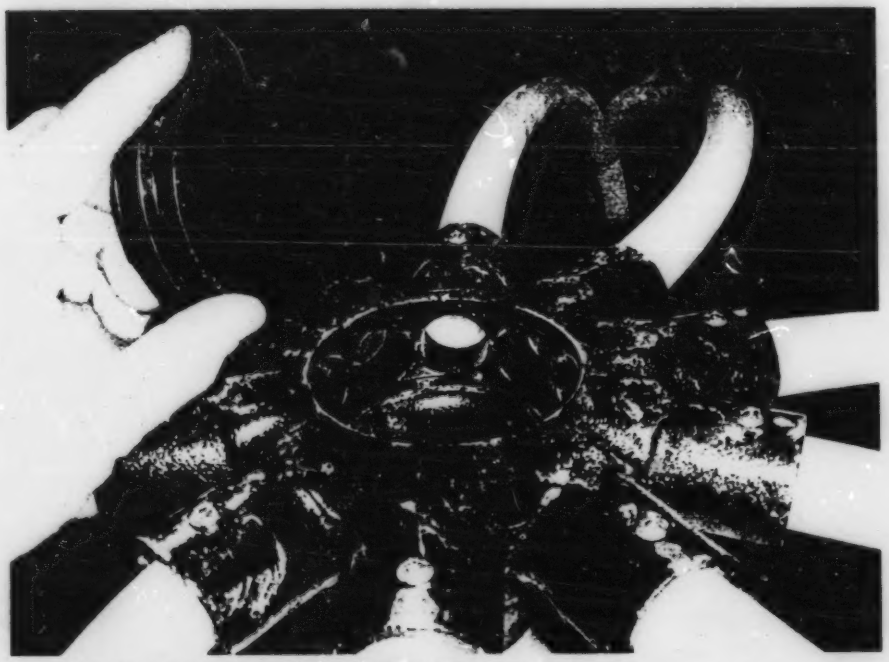


Figure 6. Quick Inspection Manifold and Poly Caps.

Ground speed, or more accurately metering roll rpm, was simulated using a hydraulic motor. The meter rpm was set by calibrating the air seeder for 4 mph (6.4 km/h). The speed of the hydraulic motor was set and monitored with a photo tachometer. Seed was placed in the large front tank due to the large seeding volumes associated with chickpea. Each manifold on the air seeder was colour coded and each delivery hose on the individual manifolds was numbered. Colour coded and numbered tubs were placed under each delivery hose for collection purposes.

Flexi-Coil: The Flexi-Coil system included a Flexi-Coil 2340 air cart with an air kit mounted on a 45 ft (13.7 m) Flexi-Coil 5000 air drill with 12 in (30 cm) spacing. Seed was metered from one long externally fluted, extra coarse, metering roll (**Figure 7**) into five individual 2.5 in (6.35 cm) ID hoses. Each hose ran to an Easy Flow Header manifold (**Figure 8**) with nine 1 in (2.5 cm) ID delivery hoses. The 1 in (2.5 cm) delivery hoses were inserted into the standard seed boot/collection tub apparatus. The metering system on the Flexi-Coil air cart was operated with the stock Flexi-Coil electronically controlled hydraulic drive system.

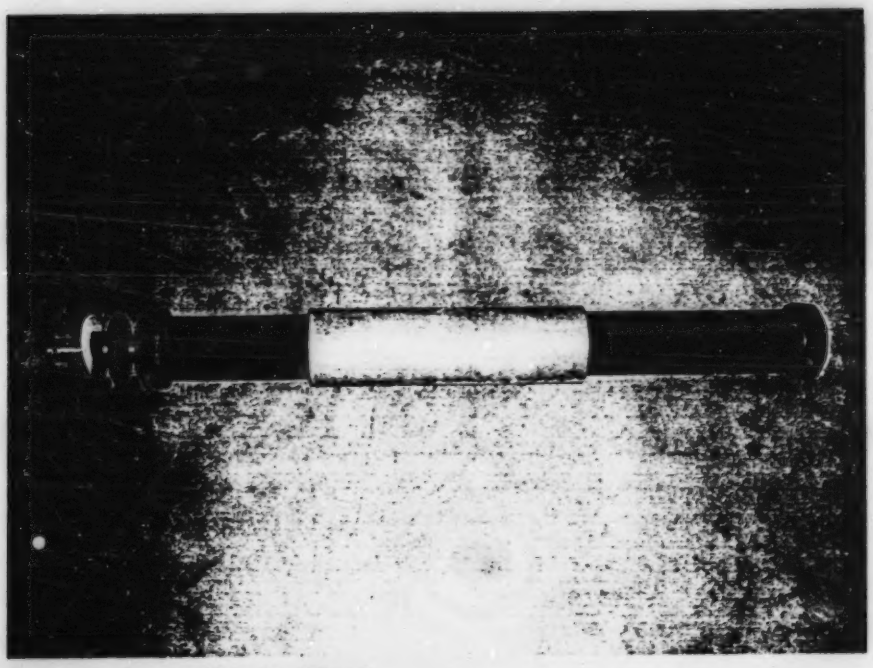


Figure 7. Coarse Metering Wheel.

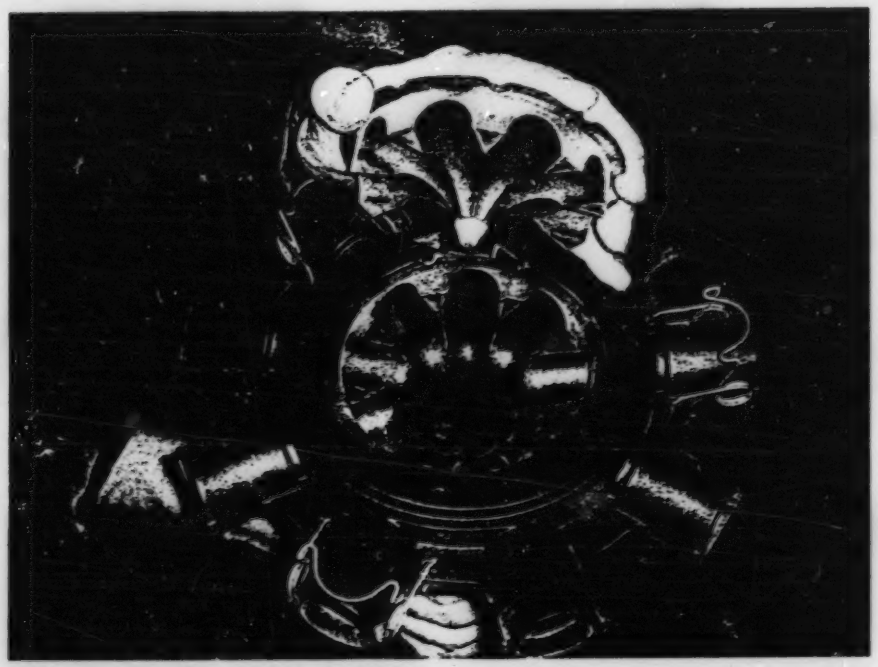


Figure 8. Easy Flow Header Manifold.

Ground speed sensing on the Flexi-Coil was simulated with an electronic device that simulated the pulse/second reading of the speed sensor located on the wheel. This was

needed for calibration purposes. An extra coarse metering roll was used to meter the CDC Yuma and CDC Xena kabuli chickpea, while a coarse metering roll was used to meter the Desiray desi chickpea. The front tank was used for all chickpea tests. The air cart was capable of dual shoot, thereby allowing the operator to set the airflow to each product stream. For testing purposes, all the airflow was directed to the front tank air distribution stream. Each manifold on the air seeder was colour coded and each delivery hose on the individual manifolds was numbered. Colour coded and numbered tubs were placed under each delivery hose for collection purposes.

Morris: The Morris system included a Morris 7240 air cart with an air kit mounted on a 40 ft (12 m) disc drill with 7.5 in (19 cm) row spacing. Seed was metered by a spiral fluted metering wheels (**Figure 9**) from the air cart into seven 2.5 in (6.4 cm) ID delivery hoses. Each hose ran to a flat fan divider head (**Figure 10**) on the seeding unit. Six of the divider heads had nine runs each, while one divider head had 10 runs. Individual seed meters were factory configured to accommodate differences in manifold outlet numbers. All runs on each divider head consisted of 15/16 in (2.4 cm) ID delivery hoses that were inserted into the standardized seed boot/collection apparatus. The metering system on the air cart was ground drive with quick-change sprockets used to vary the seeding rate.

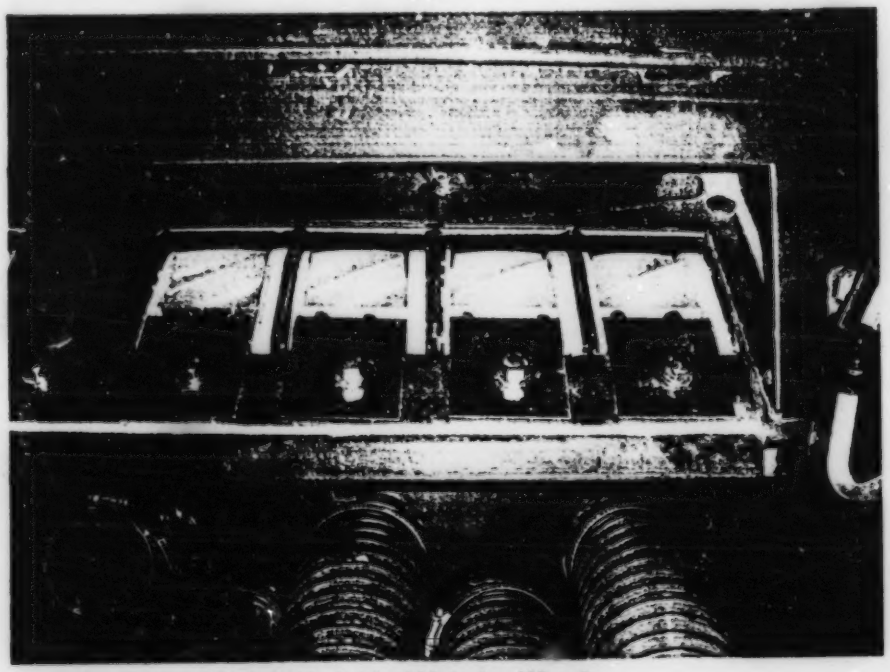


Figure 9. Externally Fluted Individual Metering Wheels.

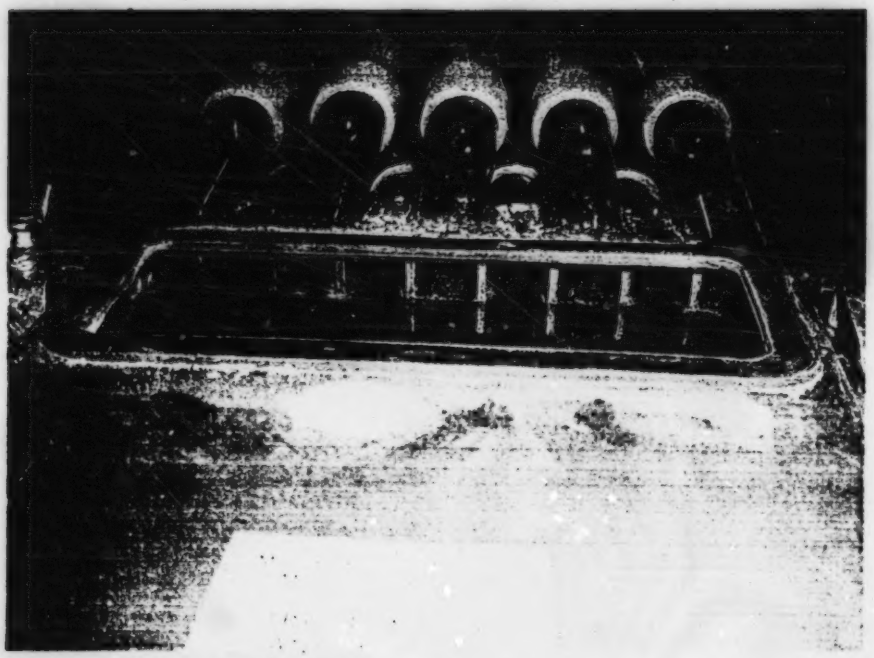


Figure 10. Flat Fan Divider Head.

Ground speed, or more accurately metering roll rpm, was simulated using a hydraulic motor to drive the meter. The metering roll rpm was set by calibrating the air seeder for 4 mph (6.4 km/h). The speed of the hydraulic motor was set and monitored with a photo tachometer. Seed was placed in the large rear tank due to the large seeding volumes associated with chickpea. The large seed metering roll was used for the chickpea tests. Each divider head on the air seeder was colour coded and each delivery hose on the individual divider heads were numbered. Colour coded and numbered tubs were then placed under each delivery hose for collection purposes.

5. Overall Air Tank/Air Delivery System Results and Discussion

Unlike the impact tests, virtually all of the CDC Yuma seed damage due to air tank/air distribution systems was due to mechanical damage (cracks, splits, and nicks) with virtually no reduction in germination in samples with mechanical damage removed. As a result, all discussion of seed damage refers to mechanical seed damage.

CDC Yuma seed metering damage was less than 1% with all three systems eliminating the metering system as a factor in chickpea damage.

The effect of ground speed on seed damage was very small. Overall seed damage through the air cart/air distribution systems was higher as fan speeds increased. However, all three manufacturers' systems resulted in low overall CDC Yuma damage of less than 3% at fan speeds of baseline to baseline +25%.

Limited air tank/air distribution system testing with CDC Desiray and CDC Xena at respective seed rates of 80 lb/ac (90 kg/ha) and 180 lb/ac (202 kg/ha) at 5 mph (8 km/h) produced similar results to the CDC Yuma testing with overall damage less than 3%.

Coefficient of variation for seed distribution was within PAMI standards (15% maximum CV) for all systems at all tested fan speeds.

5.1 Bourgault Air Tank/Air Delivery System Results and Discussion

Metering system damage with CDC Yuma at 4 mph (6.4 km/h) simulated ground speed, with the Bourgault system, was very low at 0.8%.

Baseline fan speeds for the Bourgault system with CDC Yuma at 160 lb/ac (179 kg/ha) seed rate were 2,950, 3,100, and 3,300 rpm (no load) at respective ground speeds of 4, 5, and 6 mph (6.4, 8, and 9.6 km/h). All combinations of ground and fan speeds are listed in **Table 2**.

Table 2. Bourgault Fan and Ground Speeds.

Machine	Ground Speed (mph)	Fan Speed	Actual Fan No Load (rpm)	Fan Under Load (rpm)
Bourgault	4	Base	2,950	2,970
		Base +15%	3,400	3,430
		Base +25%	3,690	3,710
		Base +70%, Max. Fan	5,010	5,210
Bourgault	5	Base	3,110	3,120
		Base +15%	3,580	3,670
		Base +25%	3,880	3,910
		Base +60%, Max. Fan	4,990	5,230
Bourgault	6	Base	3,300	3,370
		Base +15%	3,800	3,860
		Base +25%	4,140	4,180
		Base +52%, Max. Fan	5,030	5,280

Chickpea damage with the Bourgault system was very low at fan speeds from baseline to baseline plus 25% (**Figure 11**). At maximum fan speed, which is significantly higher than recommended, the damage was much higher than at the lower fan speeds. However, there would be no reason to run the system at maximum fan speed. Damage at base fan speed plus 25% was less than 3% at all ground speeds.

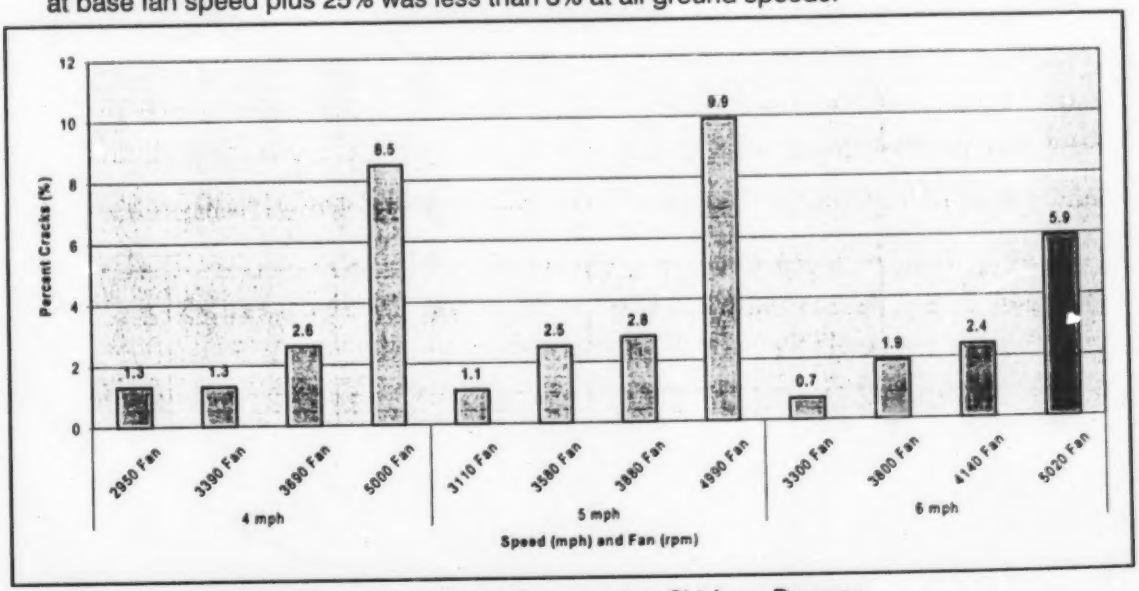


Figure 11. Effect of Bourgault Ground and Fan speed on Chickpea Damage.

Table 2. Bourgault Fan and Ground Speeds.

Machine	Ground Speed (mph)	Fan Speed	Actual Fan No Load (rpm)	Fan Under Load (rpm)
Bourgault	4	Base	2,950	2,970
		Base +15%	3,400	3,430
		Base +25%	3,690	3,710
		Base +70%, Max. Fan	5,010	5,210
Bourgault	5	Base	3,110	3,120
		Base +15%	3,580	3,670
		Base +25%	3,880	3,910
		Base +60%, Max. Fan	4,990	5,230
Bourgault	6	Base	3,300	3,370
		Base +15%	3,800	3,860
		Base +25%	4,140	4,180
		Base +52%, Max. Fan	5,030	5,280

Chickpea damage with the Bourgault system was very low at fan speeds from baseline to baseline plus 25% (**Figure 11**). At maximum fan speed, which is significantly higher than recommended, the damage was much higher than at the lower fan speeds. However, there would be no reason to run the system at maximum fan speed. Damage at base fan speed plus 25% was less than 3% at all ground speeds.

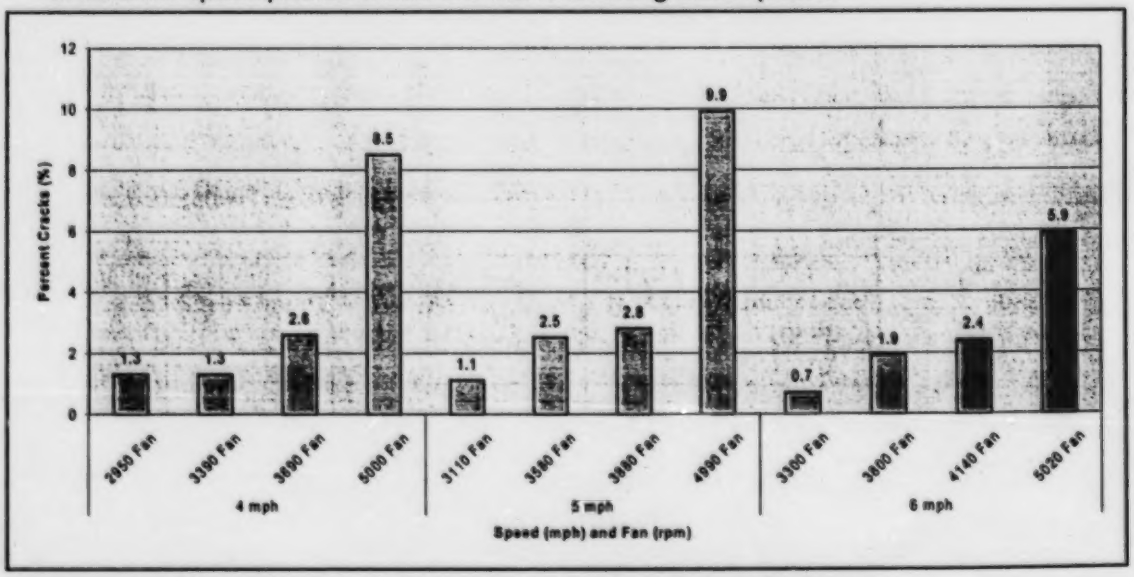


Figure 11. Effect of Bourgault Ground and Fan speed on Chickpea Damage.

The base fan speed would likely only work in ideal conditions such as a lab. The base fan speed plus 25% would be a more typical operating fan speed for in field conditions.

The single air tank/air delivery system test conducted with the two other seed varieties resulted in damage of 1.6% with CDC Xena and 2.8% with CDC Desiray, at a simulated ground speed of 5 mph (8 km/h) and fan speeds of base +25% for the Desiray and maximum fan speed for CDC Xena.

These results suggest that chickpea seed damage with the Bourgault system is very low with all tested varieties and should not be a concern to producers.

5.2 Flexi-Coil Air Tank/Air Delivery Gaps System Results and Discussion

Metering system damage with CDC Yuma at 4 mph (6.4 km/h) simulated ground speed with the Flexi-Coil system was very low at 0.1%.

Baseline fan speeds for the Flexi-Coil system with CDC Yuma at 160 lb/ac (179 kg/ha) seed rate were 3,400, 3,420, and 3,970 rpm (no load) at respective ground speeds of 4, 5, and 6 mph (6.4, 8, and 9.6 km/h). All combinations of ground and fan speeds are listed in **Table 3**.

Table 3. Flexi-Coil Ground and Fan Speeds.

Machine	Ground Speed (mph)	Fan Speed	Actual Fan No Load (rpm)	Fan Under Load (rpm)
Flexi-Coil	4	Base	3,400	3,400
		Base +15%	3,880	3,900
		Base +25%	4,220	4,250
		Base +47%, Max. Fan	5,010	5,020
Flexi-Coil	5	Base	3,420	3,430
		Base +15%	3,910	3,930
		Base +25%	4,260	4,290
		Base +46%, Max. Fan	5,010	5,080
Flexi-Coil	6	Base	3,970	3,990
		Base +15%	4,550	4,570
		Base +26%, Max. Fan	5,000	5,020

Chickpea damage with the Flexi-Coil system was very low at all tested fan speeds (**Figure 12**).

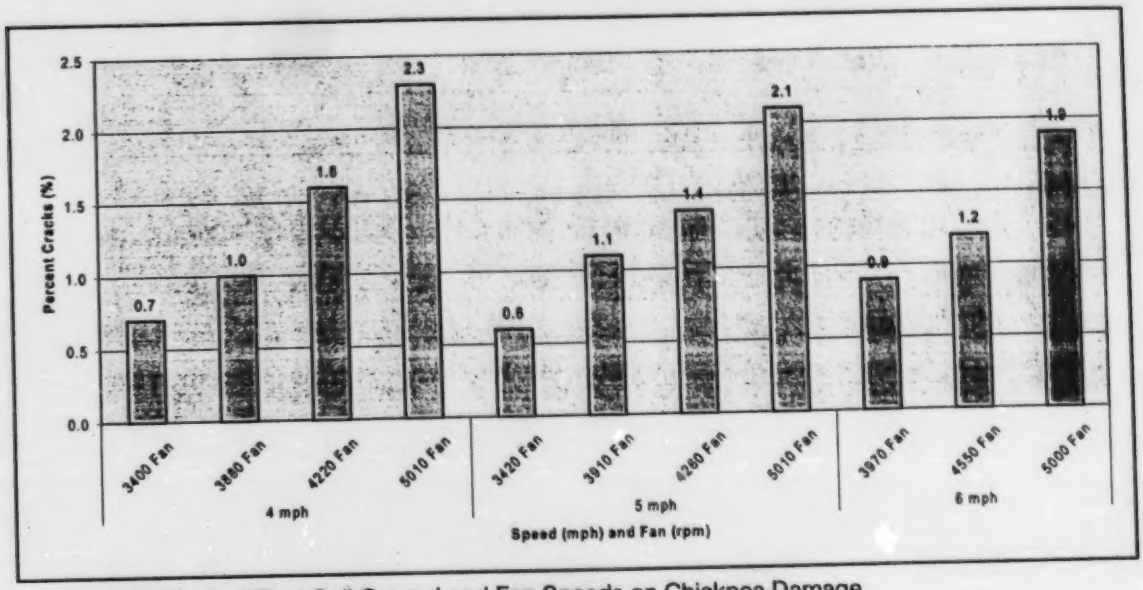


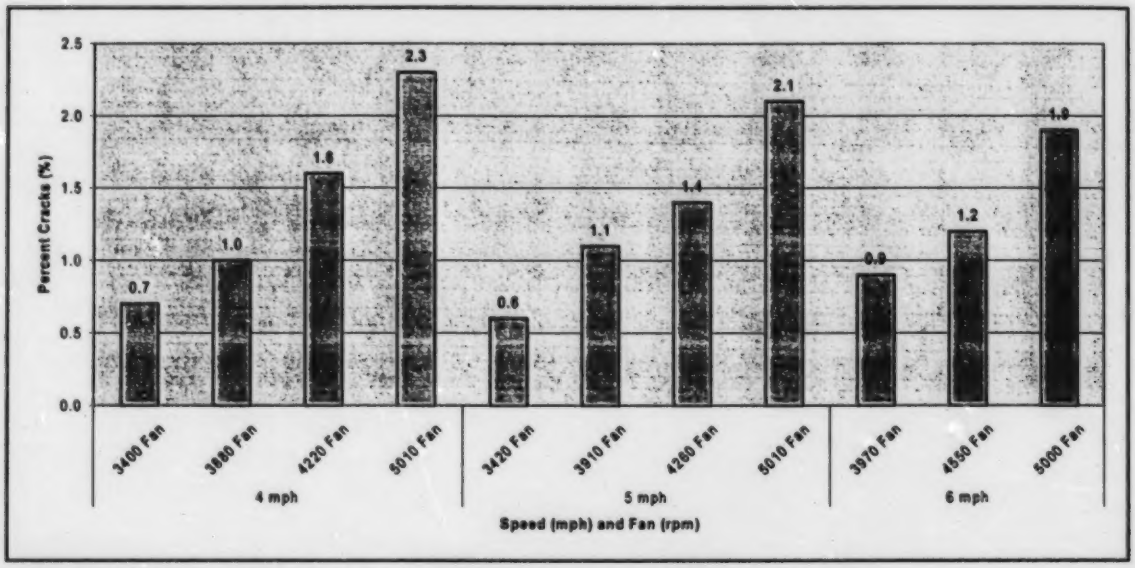
Figure 12. Effect of Flexi-Coil Ground and Fan Speeds on Chickpea Damage.

The base fan speed would only likely work in ideal conditions such as a lab. The base fan speed plus 25% would be a more typical operating fan speed for in field conditions. Although, seed damage increased at higher fan speeds, even at maximum fan speed, total seed damage was less than 3%.

The single air tank/air delivery system test conducted with the two other seed varieties, resulted in damage of 0.7% with CDC Xena and 1.2% with CDC Desiray, at a simulated ground speed of 5 mph (8 km/h) and fan speeds of base +25% for the Desiray and maximum fan speed for CDC Xena.

These results suggest that chickpea seed damage with the Flexi-Coil system is very low with all tested varieties and should not be a concern to producers.

Chickpea damage with the Flexi-Coil system was very low at all tested fan speeds **(Figure 12)**.



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These results suggest that chickpea seed damage with the Flexi-Coil system is very low with all tested varieties and should not be a concern to producers.

5.3 Morris Air Tank/Air Delivery System Results and Discussion

Metering system damage with CDC Yuma at 4 mph (6.4 km/h) simulated ground speed with the Morris system was very low at 0.2%.

Baseline fan speeds for the Morris system with CDC Yuma at 160 lb/ac (179 kg/ha) seed rate were 3,000, 3,420, and 3,800 rpm (no load) at respective ground speeds of 4, 5, and 6 mph (6.4, 8, and 9.6 km/h). All combinations of ground and fan speeds are listed in **Table 4.**

Table 4. Morris Ground and Fan Speeds.

Machine	Ground Speed (mph)	Fan Speed	Actual Fan (rpm)	Fan Under Load (rpm)
Morris	4	Base	3,010	3,030
		Base +15%	3,460	3,470
		Base +25%	3,760	3,770
		Base +67%, Max. Fan	5,020	5,120
Morris	5	Base	3,410	3,430
		Base +15%	3,920	3,940
		Base +25%	4,250	4,290
		Base +47%, Max. Fan	5,010	5,380
Morris	6	Base	3,800	3,850
		Base +15%	4,370	4,400
		Base +25%	4,750	4,870
		Base +32%, Max. Fan	5,000	5,400

Chickpea damage with the Morris system was very low at all tested fan speeds **(Figure 13)**.

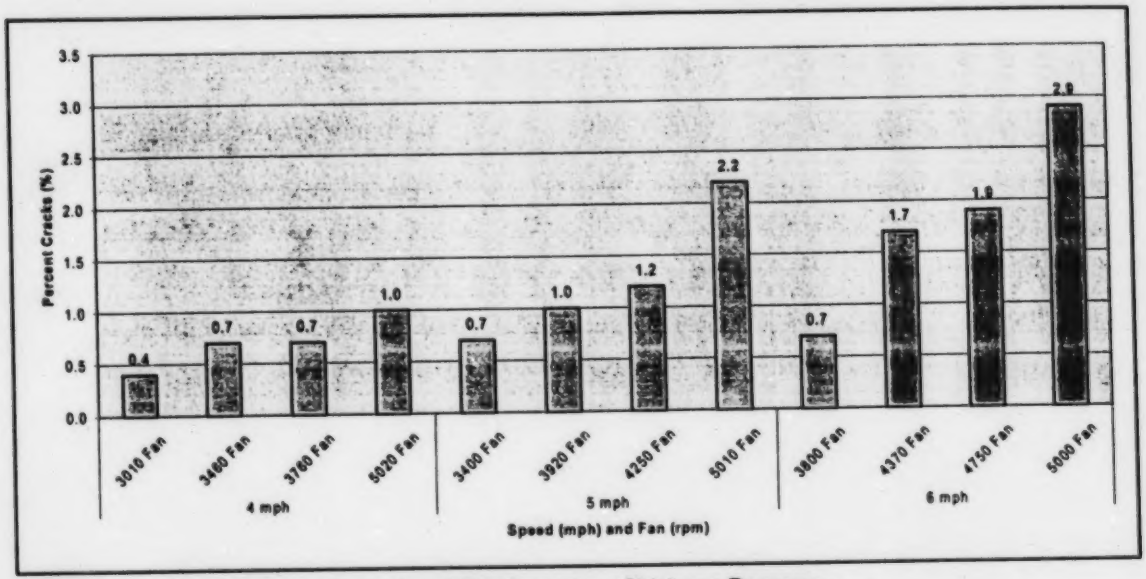

Figure 13. Effect of Morris Ground and Fan Speed on Chickpea Damage.

The base fan speed would only likely work in ideal conditions such as a lab. The base fan speed, plus 25%, would be a more typical operating fan speed for in field conditions. Although seed damage increased at higher fan speeds, even at maximum fan speed, total seed damage was less then 3%.

The single air tank/air delivery system test conducted with the two other varieties, resulted in damage of 1.2% with CDC Xena and 1.6% with Desiray, at a simulated ground speed of 5 mph (8 km/h) and fan speeds of base +25% for the Desiray and maximum fan speed for CDC Xena.

These results suggest that chickpea seed damage with the Morris system is very low with all tested varieties and should not be a concern to producers.

Chickpea damage with the Morris system was very low at all tested fan speeds (**Figure 13**).

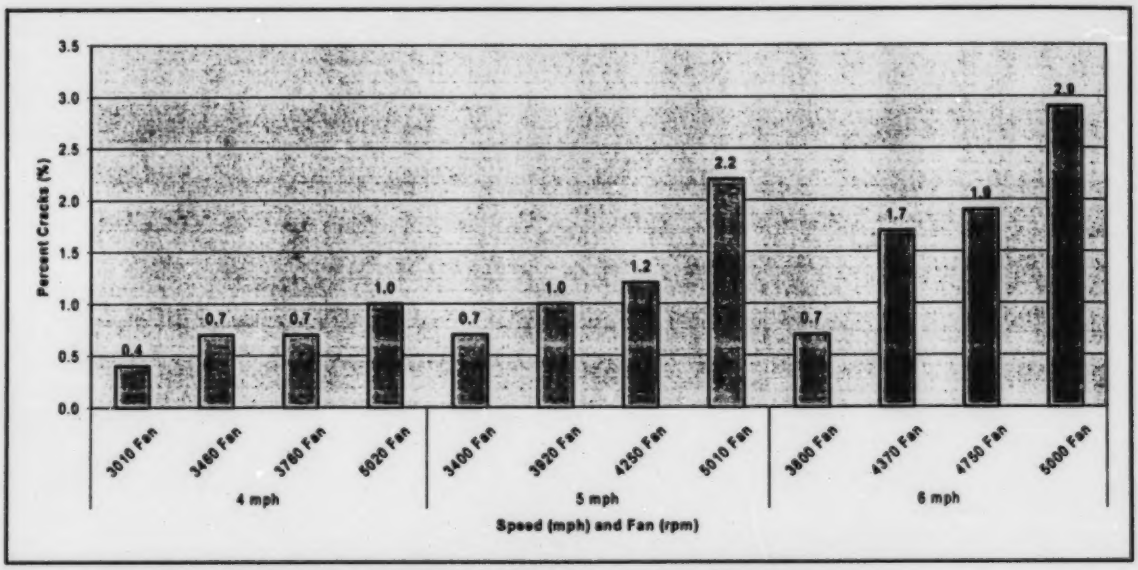

Figure 13. Effect of Morris Ground and Fan Speed on Chickpea Damage.

The base fan speed would only likely work in ideal conditions such as a lab. The base fan speed, plus 25%, would be a more typical operating fan speed for in field conditions. Although seed damage increased at higher fan speeds, even at maximum fan speed, total seed damage was less then 3%.

The single air tank/air delivery system test conducted with the two other varieties, resulted in damage of 1.2% with CDC Xena and 1.6% with Desiray, at a simulated ground speed of 5 mph (8 km/h) and fan speeds of base +25% for the Desiray and maximum fan speed for CDC Xena.

These results suggest that chickpea seed damage with the Morris system is very low with all tested varieties and should not be a concern to producers.

6. Testing Conclusion

All three air seeders provided an acceptable seeding method for chickpea. Chickpea damage was very low at up to baseline +25% fan speeds with all machines.

There is considerable variation between seed damage sensitivity within the seed types. CDC Yuma kabuli, Verna small kabuli, and nearly all desi varieties should be very carefully handled as they are prone to impact damage. This would apply to not only when seeding, but also during storage and harvest.

It was noted during testing that seed coat damage, or even removal, is not necessarily detected during the testing conducted in this project. Removal or scuffing of seed coat can cause susceptibility to soil borne disease, which will affect crop establishment. Further research to investigate the effect of invisible seed damage on crop establishment is recommended.